Vol. XII. JUNE, 1895. No. 2.

THE AMERICAN METEOROLOGICAL JOURNAL.

A MONTHLY REVIEW OF METEOROLOGY.

TABLE OF CONTENTS.

BOSTON, NEW YORK, CHICAGO, AND LONDON.

GINN & COMPANY,

Publication Office, 7-13 Tremont Place, Boston, Mass., U.S.A.

SINGLE COPIES . . 30 cents. | PER ANNUM $3.00

Entered at the Post-office, Boston, as second-class mail matter.

THE AMERICAN

METEOROLOGICAL JOURNAL.

VOL. XII. BOSTON, MASS., JUNE, 1895. No. 2.

THE THERMOPHONE; A NEW INSTRUMENT FOR OBTAINING THE TEMPERATURE OF A DISTANT OR INACCESSIBLE PLACE: AND SOME OBSERVATIONS ON THE TEMPERATURE OF SURFACE WATERS.*

HENRY E. WARREN AND GEORGE C. WHIPPLE.

THE thermophone is an instrument for measuring temperature, particularly the temperature of a distant or inaccessible place. It was devised by the writers in 1894 for the purpose of obtaining the temperature of the water at the bottom of a pond. The first experiments were so successful that we were encouraged to study further into the capabilities of the instrument with a view to adapting it to various scientific and commercial uses. These studies have led us to believe that the thermophone is an instrument of great value, not only for obtaining deep sea temperatures but for many meteorological and scientific purposes. On account of its great precision it will be found useful in physical laboratories, and its extensive range will permit its use in obtaining either very high or very low temperatures.

Most thermometers in common use are based upon the well-known physical law of the expansion and contraction of the volume of certain substances under the influence of heat and cold. They are so well known that a description of them would here be out of place.

Electrical thermometers are not as well known. They may be divided into two classes, thermal-contact and resistance.

The well-known le Chatelier pyrometer illustrates the thermal-contact method in the simplest manner. Two wires

* Read before the New England Meteorological Society at Boston, Mass., Jan. 19, 1895.

or strips of dissimilar metals are joined together at one extremity. Their other ends are then connected with a galvanometer by means of copper leading wires. As thus arranged, a current is found to flow through the system whenever there is a difference of temperature between the junction of the dissimilar metals and the mean temperature of the other ends of the same. The strength of this current varies almost directly with the difference of temperature and may be used, with the aid of a galvanometer, to measure the same. In practice the ends connected to the leading wires are kept at a nearly constant temperature by putting them in an empty bottle, or other enclosed air space. As the instrument is almost always used for very high temperatures it is often assumed that the temperature of these junctions is that of an ordinary living room, say 70° Fahr. Of course an error of a few degrees in this assumption makes little difference when the other ends of the wires are at a temperature of several hundred degrees. On account of the necessary preliminary calibration it is difficult to measure temperatures as high as 1000° C., within 10°, with this or any other instrument. The ultimate standard is the air thermometer, an extremely fussy instrument to use. In this thermal-contact method, the very small space taken up by the junction of the two wires, and the simplicity of the apparatus, makes it very valuable for obtaining high temperatures; indeed, the junction itself may be plunged into molten metal without affecting the accuracy of the instrument in the least. The greatest objections, perhaps, are the necessity for a sensitive galvanometer and the space taken up by the same; and the occasional breaking of the wires, which necessitates recalibration. The instrument is not well adapted for obtaining temperatures at any great distance. Ordinarily, when platinum and platinum-iridium wires are used, the curve representing the relation between temperature and galvanometer deflections is nearly a straight line for temperatures higher than 400° C.

The thermo-pile is an ancient and little used instrument for determining slight changes in temperature. It is the same in principle as the foregoing, but instead of using the junction of two dissimilar strips a great many such strips are connected in series, as the zinc and carbon plates of a battery are connected. There are thus two sets of junctions with a large num-

ber of wires running between. Each pair of junctions adds its electro-motive force to the others, and the result is an extremely sensitive instrument. Of course the readings depend upon the difference of temperature between the two sets of junctions, and are of no value for getting absolute results. The method has been used almost exclusively for qualitative work.

Before proceeding to a description of some of the resistance thermometers that have been made, it will be well to consider an instrument universally used by electricians for the measurement of resistances, namely the Wheatstone Bridge. This consists of an arrangement of resistances and conductors as shown in Fig. I.

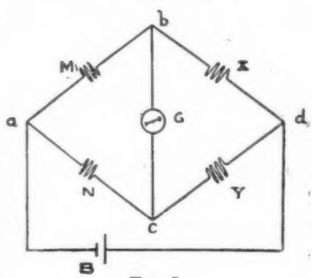


FIG. I.

The circuit of a battery, B, is divided between *a* and *d* in such a manner that a portion of the current is obliged to pass through *a c d* and the inserted resistances N and Y, while the remainder of the current passes through *a b d* and the resistances M and X. The points *b* and *c* are connected by a circuit in which is placed a galvanometer, G. By means of Ohm's law it can be shown that when the ratio of the resistances M to N is the same as that of X to Y, the potential at *b* will be the same as that at *c*, and no current will pass through the circuit connecting those two points; consequently the galvanometer, G, will show no deflection. In that condition the bridge is said to be balanced, and any one of the resistances, M, N, X, or Y, may be calculated if the other three are known.

Many resistance methods for the determination of temperature have been used. All depend upon the fact that the resistance of any substance to the electric current varies with the temperature of the conductor. Therefore it is readily seen that any apparatus capable of measuring the resistance of a material may also be used to measure its temperature, because one is a function of the other. It is a curious fact that the electrical temperature coefficients of most pure metals are nearly equal, and are almost exactly the same as the temperature coefficients of the expansion of gases. It is also a fact that the electrical

temperature coefficients of the alloys of metals are very different from those of their components, being almost invariably lower.

The simplest apparatus for measuring temperatures is an ordinary Wheatstone Bridge, such as has already been described. A coil of insulated copper, iron, or platinum wire is connected to the rest of the bridge by heavy leading wires. The resistance of this coil is measured at a given temperature, say 0° C; then its resistance at other temperatures may be determined by experiment or by calculation. A curve showing the relation between the temperature and resistance is usually drawn. For certain kinds of work where time is no object this arrangement answers well. It is necessary, however, to use a thermometer in connection with the bridge coils in order to obtain absolute results; for the resistance of these coils also varies with the temperature. For measuring temperatures at a distance there is a serious difficulty in the use of this method on account of errors introduced by the changes in temperature of the leading wires. These wires are invariably made of copper, on account of its low specific resistance. As this substance changes its temperature at the rate of about one per cent for every 5° F., it is easily seen that considerable changes in its resistance are liable to take place. For example, let us suppose that it is desired to measure the temperature at a place one thousand feet away, and that the coil to be used at the distant point is made of copper and has a resistance of one hundred ohms. Now, if the conducting wires be about 0.1 inch in diameter, the weight of the line wire will be about sixty-two pounds, exclusive of insulation, and its resistance will be two ohms. Evidently the change in reading caused by a change in temperature of the line wires will be one-fiftieth as great as that produced by a like change in the resistance coil. But the line wires are liable to be subjected to great variations in temperature: a change of 50°F. might easily occur, introducing an error of 1° in the final result. This error might be reduced in two ways: first, by increasing the size and weight of the line wires, which are already exceedingly heavy; or, second, by increasing the resistance of the coil. This could be done up to a certain limit, but would add considerably to the expense of the apparatus. As a matter of fact this method is not suitable for long distance work.

A very great improvement over this primitive arrangement was suggested by Siemens in 1883. His idea was to eliminate the errors introduced by the leading wires by making one of them compensate for the other. This he did in the simplest possible manner, by running the wire which connects one pole of the battery ordinarily with a point on the line wire near one of the bridge coils, to the distant end of the same line wire, thus throwing it into the other side of the bridge. As a result any change in temperature causes one lead wire to pull the reading of the instrument in one direction and the other wire to pull it in the opposite direction.

Fig. II. represents Siemens' arrangement as used on the "Challenger" expedition of 1884. The temperature coil A, and a coil B, equal in resistance to A and constructed of the same material, were put into adjacent arms of a Wheatstone Bridge. The other two arms, C and D, were made equal to each other. A sensitive galvanometer G was used to indicate when a balance of the bridge had been obtained. The plan of procedure was to immerse the coil B in a tank of water while the coil A was lowered into the sea. In order to find the temperature of the coil A, it was only necessary to make the temperature of the water in the tank, in which the coil B was immersed, such that there was no deflection of the galvanometer. Evidently this temperature was exactly equal to that of the coil A; for, by assumption, the coils A and B were equal in resistance only when at the same temperature. The two leading wires were always of equal resistance, being twisted together and having, therefore, the same average temperature. Good results may undoubtedly be obtained by this method if the operator has sufficient patience. It is slow work, however, for the tank of water must be adjusted in temperature gradually and with great care. A mercurial thermometer must be used to determine the temperature of the water in the tank. The apparatus is not at all portable. It was estimated on the "Challenger" expedition that five minutes were consumed in setting and five minutes more in reading.

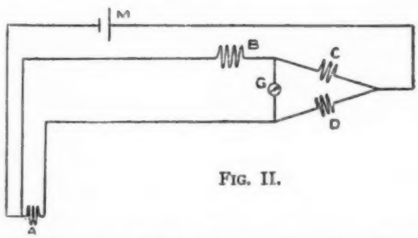


FIG. II.

An improvement over Siemens' apparatus was made by Hugh Callendar in 1887. A simplified diagram of his arrangement is shown in Fig. III.

Two coils, A and B, of the same metal, copper, for instance, were arranged on diagonally opposite sides of a Wheatstone Bridge. These coils were exactly equal in resistance when at the same temperature. The resistances C and D, by a double slide wire were always exactly equal the one to the other, though variable. With this arrangement it can be shown that the bridge will balance only when A, B, C, and D are all equal. $A + B$ is a function of the temperature; but $A + B = C + D$, and $C + D$ may be read from a scale under the slide wire. Therefore the scale reading is a function of the temperature of A and B. The leading wires, L, L^1, produce no effect on the result. By this means absolute and not relative measurements may be obtained, but the apparatus is complex and expensive.

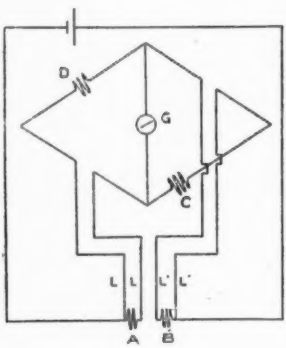


FIG. III.

There have been other methods suggested for finding the temperature of a distant point, most of them being combinations of electrical and mechanical devices. One of these consists of an enormous iron thermometer bulb and stem filled with mercury in the usual manner. At intervals in the stem of the thermometer are inserted metallic pins, upon touching which the mercury closes a circuit operating an electrical signalling device at some distant place.

Another and a much better instrument for transmitting temperature readings consists of an ordinary metallic thermometer whose hand carries a small roller along a circular form of slide wire bridge. This arrangement is shown in Fig. IV.

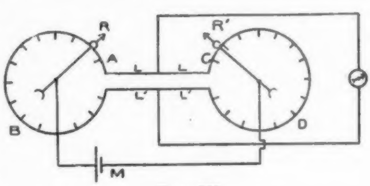


FIG. IV.

The small roller, R, and the ends of the slide wire, AB, are joined by suitable electrical conductors, L, L', to a similar device at the other end. This other instrument is arranged so that its pointer may be moved by hand or by a small motor. When suitably adjusted, a galvanometer, G, inserted as shown in the diagram, will show zero deflection only when the reading of one instrument is equal to that of the other. The chief defects of this apparatus are the metallic thermometer and the delicacy of the transmitting apparatus. It would be very difficult to use the instrument under water.

The apparatus invented by the authors of this paper, and which is here presented to your inspection, resembles Siemens' resistance thermometer more than any other. We have taken advantage of the fact that different metals have different electrical temperature coefficients. Fig. V. illustrates the general arrangement.

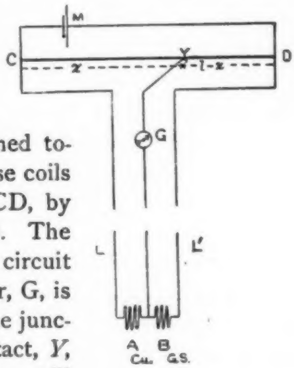


FIG. V.

A and B are coils of different metals placed in proximity and joined together as shown in the figure. These coils are connected with a slide wire, CD, by means of the leading wires L and L'. The two ends of CD are connected in circuit with a battery, M. A galvanometer, G, is put into a leading wire connecting the junction of A and B with a movable contact, *Y*, on the slide wire. The galvanometer will indicate zero current when $\frac{A}{B} = \frac{Cy}{Dy}$. But A and B having different temperature coefficients will vary in resistance at different rates with changes in temperature; consequently there will be a different value of $\frac{A}{B}$ for every temperature. The value of $\frac{}{B} = \frac{Cy}{Dy}$ may be directly read from a scale placed under the sliding contact, *Y*, or the temperature corresponding to the given ratios of $\frac{}{B}$ may be marked upon the scale.

In practice the slide wire is wound around the edge of a disk above which there is a dial graduated in degrees of temperature. The hand on the dial is directly over the movable contact on the slide wire, and both are moved by turning a knob in the centre of the dial.

It is easily seen that the temperature of the slide wire, CD,

has absolutely no effect upon the reading of the instrument, for being made of one piece of metal which has the same temperature throughout its length, each portion of it will rise or fall in resistance at the same rate with changes in temperature ; consequently the ratio of its parts will not vary. The effect of temperature changes on the leading wires [L and L^1] will not sensibly affect the readings for the same reason as in Siemens' apparatus. In place of the galvanometer we have often found it advisable to use a telephone in connection with a circuit breaker to show the presence of a current. This instrument is cheap, light, and very durable and may be used in any place not excessively noisy.

We will next consider the theory of the instrument as it relates to the character and precision of the scale readings. Referring back to Fig. V., C D represents the slide wire, whose length is l, and on which y is the null point. A and B are the resistance coils, which are usually made of copper and german silver respectively. Let $Cy = x$; then Dy will equal $l - x$. According to the theory of the bridge the resistance of the copper coil A is to the resistance of the german silver coil B as x is to $l - x$, *i. e.*,

$$\frac{R_{Cu.}}{R_{G.S.}} = \frac{x}{l-x}$$

If the resistance at 0° C. is called unity, the above formula may be applied to any temperature, t, by inserting the temperature co-efficients for the two metals, *i. e.*, —

$$\left\{\frac{R_{Cu.}}{R_{G.S.}}\right\}_t = \frac{1 + 0.003824t + 0.00000126t^2 + \ldots}{1 + 0.0004433t + 0.000000152t^2 + \ldots} = \frac{x}{l-x}$$

Simplified, this equation becomes

$$\frac{x}{l-x} = 1 + 0.0033807t - 0.000000391t^2 + \ldots.$$

This equation contains but two unknown quantities, t and x; hence, by assuming certain values for t we may calculate the corresponding values for x, that is, we may find the theoretical reading on the bridge corresponding to any temperature of the coils, or, given any bridge reading, we may find the corresponding temperature. But it should be remembered that the above constants are true only for a comparatively limited range of temperature.

For example, let us assume that the null point y be found at the extreme end of the bridge, at C. In that case $x = o$, and the corresponding value of t is found to be —286° C., which is very near the absolute zero. If we assume that the null point falls at the other end of the slide wire D, the corresponding value of t is infinity.

Between these two points the line representing the relation between t and x will be the curve whose equation is given by the above formula. This curve has been plotted from 0° to 100° C. It is very nearly a straight line. It has been found that the length of a degree gradually decreases towards the upper part of the scale, but the difference is so small that it is hardly perceptible. Between points five Fahrenheit degrees apart, the variation in the length of a degree is not greater than 0.01°.

In regard to the length of the scale divisions, it will be seen from Fig. V. that they are susceptible of great variations because the length of the slide wire may be varied at will. We have made an instrument in which the length of a degree (Fahr.) is 10 cm. With this scale each millimeter represents 0.01°, and it is possible to read even closer than that. Practically, however, it is seldom necessary to read closer than 0.1° Fahr., and often a less precision is sufficient. For ranges of temperature between 30° and 80° we have found it convenient to use a dial five inches in diameter, on which the degrees are about 0.3 inch long. It should be said that the intensity of the sound in the telephone is independent of the length of the scale division. Therefore, as far as the sound is concerned, it is just as easy to read to tenths of a degree on a small as on a large scale.

One very important advantage of the thermophone is the rapidity with which it sets. For many purposes a quick-setting instrument is necessary, and is in all cases desirable.

By covering our resistance wires with substances having good heat conducting powers, by making the mass of this protective covering as small as possible, and by giving it a great radiating surface, we have succeeded in producing an instrument which will set more rapidly than a mercurial thermometer.

The following table shows a comparison between the thermophone and one of Green's chemical thermometers as to the time of setting. The figures given in the table represent the average of several sets of observations :—

TIME OF SETTING.

COMPARISON BETWEEN THERMOPHONE AND THERMOMETER.

	TEMPERATURE READING.	
Time in seconds.	Thermophone.	Thermometer.
0	70.8	68.9
10	46.7	36.3
20	36.7	33.0
30	33.2	32.7
40	32.5	32.5
50	32.4	32.4
60	32.3	32.4
70	32.1	32.3
80	32.0	32.3
90		32.2
100		32.1
110		32.0

The experiments were made by transferring the instruments from a water bath of about 70° Fahr. to a mixture of melting snow, the temperature of which was known to be exactly 32°. The mercurial thermometer fell rapidly at first, reaching 33° in 20 seconds: after that it dropped slowly, requiring 110 seconds to reach the exact temperature. The thermophone, on the other hand, dropped more slowly at first, requiring 30 seconds to reach 33.2°, but it fell more rapidly over the remaining tenths, reaching the freezing point in 80 seconds, which was one half a minute less than was required by the thermometer.

For obtaining deep sea temperatures a quick setting thermometer is of advantage because it effects a great saving of time. The Negretti and Zambra thermometer, which is the one usually used by the government for deep sea work, sets very slowly. Dr. Kidder, in his report on the thermometers used by the United States Fish Commission in 1885, mentions two experiments which were made to determine the time of setting of the Negretti and Zambra instruments. These thermometers, it will be remembered, are mercurial ones, having a large cylindrical bulb. Just above the bulb the tube has a peculiar bend, at which point the mercury breaks when the thermometer is inverted. Readings are obtained by inverting and allowing the mercury above the bend to fall to the other end of the tube, where suitable graduations are made. Of the two thermometers tested by Dr. Kidder one required

seven minutes and the other fifteen minutes to register the correct reading, when changed from a bath of about 70° to one of melting ice. When these thermometers are used in practice, it is customary to allow them to set ten minutes before inverting. Besides slowness in setting, the Negretti and Zambra thermometers have other disadvantages which need not be mentioned here.

It is evident that the thermophone is capable of doing better and more rapid work than the Negretti and Zambra instruments. Not only is less time required for setting, but much time is gained by not being obliged to haul it to the surface whenever a reading is to be taken. In most of our work with the thermophone where we were taking temperatures of the water at intervals of one foot in depth, and where the changes between successive readings were slight, we were able to take observations as often as once a minute.

As we have already stated, the thermophone was first used for obtaining the temperature of the water at the bottom of Lake Cochituate, one of the sources of the Boston Water Supply. It may be interesting in this connection to review some of the temperature observations which have made in connection with the biological studies of that water supply.

The Biological Laboratory of the Boston Water Works was established at Chestnut Hill Reservoir in 1889, and since Jan. 1, 1890, weekly microscopical examinations of samples collected from all the reservoirs have been made. It has been found that the seasonal occurrence of many of the micro-organisms found in the water is influenced to a considerable extent by physical changes resulting from the varying temperature of the water ; for example, the diatoms and many of the infusoria are most abundant in the spring and fall, or during the two seasons of the year when the water in the reservoirs circulates freely from the top to the bottom. It has, therefore, been the custom to record the temperature of each sample of water collected for analysis. In addition to this, several series of temperature observations have been taken in the deep reservoirs during the summer season at intervals of five feet in the vertical from the top to the bottom.

The thermometers used for these observations were nine inches long, graduated to half degrees on the stem from 0° to

120° Fahr. For protection they were mounted in wooden cases weighted at the bottom. In order to obtain the temperature of the water below the surface, the thermometer was placed in a gallon bottle, enclosed in a metal frame, to which the sinking cord was attached. A cork stopper with a separate cord was put into the mouth of the bottle where it remained during the descent. When the required depth had been reached, the cork was pulled and the bottle allowed to fill with water. After waiting about ten minutes in order that the thermometer should acquire the temperature of the water at that depth, the bottle was drawn rapidly to the surface and the reading taken without removing the thermometer from the bottle. This method involved several sources of error, but there is reason to believe that most of the results were correct within half a degree. With sufficient care, a much greater precision may be obtained by this method.

Plate I. shows the temperatures at the surface and bottom of Lake Cochituate, Chestnut Hill Reservoir, and Basins 2, 3, and 4. The observations were taken weekly from Jan. 1, 1890, to Jan. 1, 1895, and the curves were plotted from the monthly means which are published yearly in the Annual Reports of the Boston Water Board. The surface temperatures, being practically the same in the different reservoirs, have been shown as one line. It will be noticed that the temperature of the water at the bottom of the reservoirs depends largely upon the depth. In Basin 2, which is about twenty feet deep at the point where the observations were taken, the temperatures at the surface and bottom during the summer are almost the same. Basin 3 is twenty-five feet deep, and the bottom temperature is lower than in Basin 2. During a portion of the summer the lower layers are quite stagnant, that is to say, there is no vertical circulation. In Chestnut Hill Reservoir, twenty-eight feet deep, and in Basin 4, forty-five deep, the summer temperatures at the bottom are still lower. The rise of the temperature at Basin 4 during September is occasioned by the drawing down of the water to supply the city. In Basins 2 and 3 the temperatures are also influenced by the drawing down of the surface. In Lake Cochituate, sixty feet deep, the bottom temperature is lower than in the other reservoirs, and is quite constant during the summer. In Chestnut Hill Reservoir and in Basins 3 and 4

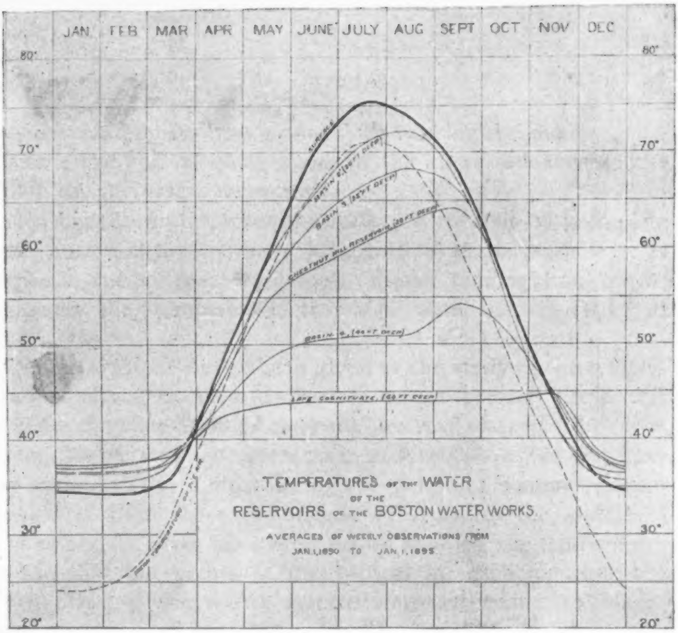


PLATE I.

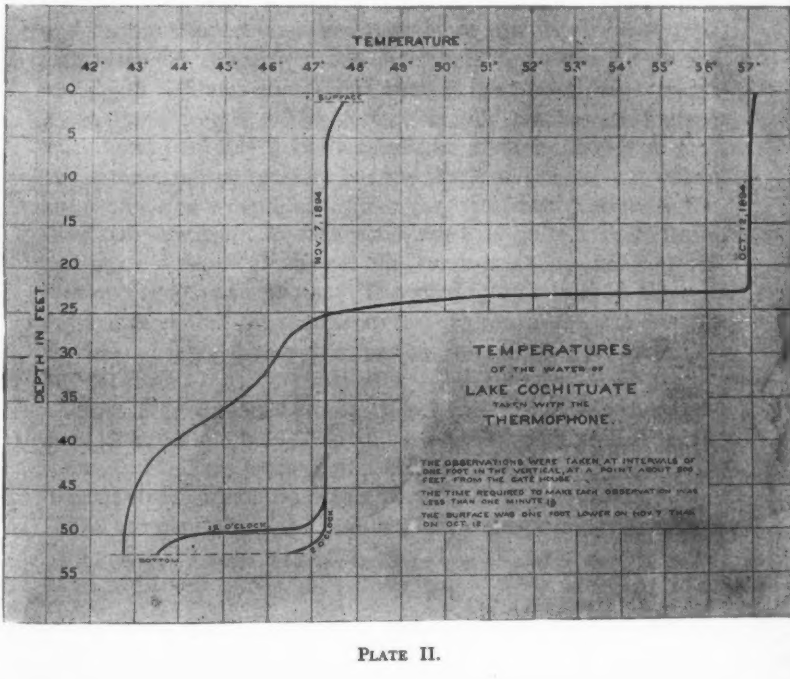


PLATE II.

the bottom temperatures gradually rise during the summer. In Basin 4 the rise is quite slow; in the reservoirs having less depth the increase is more rapid.

During the winter, when the surface is covered with ice, the temperature at the bottom is higher than at the surface.* It varies in the different reservoirs, always tending, however, to approach the temperature at which water is densest, *i. e.*, 39.2° Fahr.

Especial attention has been given to the study of the temperature of Lake Cochituate, because of its greater depth and because the stagnation phenomena are very marked. For four years observations have been taken at intervals of five feet from the surface to the bottom during the period of summer stagnation, *i. e.*, from about the middle of April to the middle of November. Curves have been drawn showing the temperature at the different points in the vertical for each month of the year. During the winter months from December to March these curves are very much alike. In April the water begins to warm up, especially at the surface. In May the water is warmer at all depths, and the difference between the surface and bottom temperatures becomes more marked. From June to September the curves are practically the same below the mid-depth. Above that point they differ somewhat, though similar in character. The surface usually reaches its highest temperature in July. In October the surface temperature is about the same as for May, but the shape of the curve is different. Down to a depth of 15 feet the water has practically the same temperature. At that point there is quite a sharp turn, and below a depth of 20 feet the curve is about the same as that of the summer months. The stirring up occurs in November and after that the temperatures are nearly the same at all depths. In November the bottom temperature reaches its highest point.

From May to October the curves are reversed curves, the point of inflection being found between 15 and 20 feet below the surface. This is the point where there is the greatest difference of density of the water per foot of depth.

The temperature at the bottom during the period of summer

* The "surface" temperatures during the winter were taken one foot below the ice.

stagnation is not the same every year. It has been found that the weather during the month of April determines the temperature at which the bottom will remain during the following summer. After the ice breaks up in the spring, the water circulates throughout the vertical. The surface and bottom temperatures are then practically the same. As the weather grows warmer these temperatures rise. If there were no wind the bottom temperature would cease to rise as soon as the point of maximum density had been reached. But on account of the wind, and because in that part of the scale the difference in density per degree is very slight, the bottom temperature rises higher than 39.2°. It continues to rise as long as the difference between the surface and bottom temperature does not exceed about 5°. But with the first "warm wave" the surface temperature rapidly rises, and gains 5° or more over the bottom temperature. The difference of density corresponding to this difference of temperature is usually sufficient to prevent the wind from keeping the water in circulation, consequently the water at the bottom becomes stagnant and its temperature remains constant at the point where it was when circulation ceased.

In the fall, stagnation does not cease until the temperature of the surface has fallen to within about 5° of the bottom temperature. After that point has been reached the first high wind generally stirs up the water to the bottom. This "turning-over" usually occurs during the second week in November.

In 1894 the turning-over occurred earlier than usual, on account of the cold stormy weather during the first few days of November, and was especially interesting on account of its suddenness. Fortunately we studied it with particular care, and the thermophone enabled us to determine the temperature at all points in the vertical with great accuracy.

Two of the curves obtained with the thermophone are shown in Plate II. Observations were taken at intervals of one foot in the vertical, and in no case did the readings differ from the curves as plotted by more than 0.1° Fahr. On Oct. 12, the surface temperature was 57.15°. It decreased slightly to 5 feet, and from that point to a depth of 23 feet it was exactly the same. Between 23 and 23.5 feet the temperature dropped rapidly and observations were there taken for each inch of depth. Below 23.5 feet the temperature decreased more slowly. The sharpness of the

curve at 23 feet was quite remarkable. Readings at that point were several times checked to insure correct results. On Nov. 7, after the severe snow storm and during a high wind, observations were again taken with the thermophone. On that day the temperature was uniform at 47.3° to a depth of 46 feet, save for a slight increase at the surface, the effect of the sun. At twelve o'clock the temperature at the bottom was 43.5°. Between 48 and 51 feet the temperature was variable, changing sometimes several degrees in less than a minute. Several series of observations were made at intervals of six inches, which showed that the water at that depth was in a state of commotion, and that the temperature at each point was gradually rising. No readings were obtained between twelve and two o'clock. At 2 P. M. the water had practically turned over. The temperature at 51 feet was 46.8°. At 51½ feet, with the coil partially immersed in the mud at the bottom, the reading was 46.5°. The change that occurred during the two hours between twelve and two o'clock was remarkable. The difference between the character of the water before and after the turning over is strikingly shown by the color.

		Color (Platinum Standard).	
Date.	Time.	Surface.	Bottom.
Nov. 7, 1894.	8 A. M.	0.32	0.95
"	2 P. M.	0.33	0.47

In the winter when the surface is covered with ice the water at the bottom again becomes stagnant. By means of the thermophone we have carefully studied the temperatures of the different strata of water under the ice. The results are most interesting but there is not time to consider them in this paper. It may be said, however, that the water immediately under the ice has a temperature only slightly higher than the freezing point; that during the first five or ten feet below the surface this temperature increases rapidly; that below that depth the change is more gradual; and that at the bottom the temperature tends to approach that of maximum density.

Another purpose for which the thermophone is admirably fitted is that of obtaining the temperature of the soil at various depths below the surface. Heretofore there has been considerable difficulty in getting accurate observations, especially when the ground was frozen or covered with snow. We believe that

by the use of the thermophone it is possible to obtain more reliable data on the temperature of the soil at all seasons of the year than can be obtained in any other way.

In order to test the capabilities of the instrument we located two thermophone coils under a lawn, one six and the other seven inches below the surface. As there was no special object in having a quick setting instrument, the resistance wires were enclosed in a cylindrical brass tube, one inch in diameter, instead of in a tube of small bore, wound in a helix. Leading wires from these coils were carried to the house, where the readings were taken. Observations were made hourly during the day and evening from Nov. 15 to Nov. 22, 1894. The results when tabulated and plotted brought out several interesting facts, the most important being the extreme sensitiveness of the instrument and the almost perfect smoothness of the curves.

It was interesting to notice how the temperature of the soil at that depth followed the air temperature, the maximum for the day usually occuring a few hours after noon; and also how the changes in the seven-inch coil lagged behind those of the coil six inches deep. When the ground became frozen the daily variation became very slight.

A more extensive series of observations was begun in December, 1894, five coils being located under a lawn at depths of 4 inches, 1, 2, 3, and 4 feet. These coils were located in what was practically undisturbed soil, by digging a hole and then boring horizontally into the ground, locating the cylindrical coils at the ends of these drifts. The leading wires from these coils were carried into the house and connected to a single dial, where by means of a suitable switch board, the temperature of one after another could be obtained. The results of these observations will be published at some future time.

It is apparent that the thermophone will be of service in many kinds of meteorological and commercial work. For ascertaining the temperature of inaccessible places, such as mountain tops or artesian wells, the instrument will be likely to prove of great value; while it may be used to some extent in place of mercurial thermometers, especially for very low or very high temperatures. It is probable that a recording type of thermophone will be produced soon. This, on account of its very great precision, would possess advantages over any other form of registering thermometer.

CALIFORNIA ELECTRICAL STORMS.*

JOHN D. PARKER.

ONE of the peculiar features of the weather of Southern California is the infrequency of electrical storms. In San Diego, people do not protect their buildings against lightning, and the writer has been unable to discover a lightning rod in Los Angeles. The Weather Bureau has reported only two electrical storms at San Diego during the last sixteen years.

One of these storms occurred on Aug. 27, 1894, and it may be taken as a type of all electrical storms in this region. On that day there prevailed a close, sultry atmosphere, with a stoppage of the sea-breeze, replaced by fitful currents of hot air from the desert, and a filmy vapor cast a slight veil over the face of the sun. About midday the observer, at San Diego, from the roof of his building, saw far to the south, fifteen or twenty very small thunder-heads, appearing conical above with flat bases. These thunder-heads moved slowly northward along the San Jacinto mountain range, and arrived opposite San Diego about sunset, where, by the enlargement of the visual angle, they seemed to fill the whole heavens with black masses of cloud. The edge of this Sonora brushed by San Diego that evening, with an electrical display which was quite vivid in the mountains. This storm brought to San Diego a warm shower of rain which measured .4 inch. A bolt of lightning struck a wire in the city, and burnt out the coil of one of the dynamos in the engine-house, which extinguished for a brief period the incandescent lights all over the city.

Lightning sometimes plays a little among the clouds far out over the ocean, and occasionally thunder mutters in the mountains, but the Weather Bureau reports that, during the last sixteen years, not a single thunderstorm arising from general cyclonic action has occurred at San Diego. The thunderstorms of this region are Sonoras, that move northward two or three times a year from Sonora and contiguous regions, where they originate. They seem to be formed, like ordinary thunder-

* Summary of a paper read Dec. 28, 1894, before the California Science Association.

storms, from vapors evaporated from the Gulf of California and regions lying adjacent, and moving northward along the San Jacinto Range, on both sides of the mountains, exhibit electrical displays until their forces are exhausted, and they are dissipated. The hot stratum of air lying along the elevated portion of this mountain range, during the summer, would naturally be pushed into the higher regions of the atmosphere to condense vapor into cloud, and lateral surface currents would flow in on both sides to feed the Sonoras in their onward movement.

California as a State has few electrical storms, and portions of southern California are entirely free from such disturbances arising from regular cyclonic causes. The Director of the California Weather Service, in his Annual Review for 1893, reports only forty-three storms over the whole State that were accompanied with lightning.

It is the purpose of this paper to inquire into the causes for the infrequency of electrical storms in California, particularly in the southern portion of the State. In a general survey of this subject, it must be observed that the southwestern portion of the United States lies most remote from the normal paths of cyclonic action, which takes effect along the forty-ninth parallel of latitude, and along the Atlantic coast from the West Indies northward. In this remoteness from cyclonic action we shall undoubtedly find one general cause for the infrequency of electrical disturbances in California, and Lieut. John P. Finley, that eminent meteorologist and successful forecast officer, emphasizes this fact. It is evident, however, that this cause is not sufficient to account for this anomaly, and that other causes must be operative. Electrical displays are very frequent during the rainy season in portions of Arizona nearly as far removed from these normal paths. For a full explanation of this anomaly we must look to other causes connected with meteorological conditions in California.

One cause for the infrequency of electrical storms is probably found in the humidity of the atmosphere. The vapors of the earth ascending into the upper regions of the atmosphere are condensed into clouds which fall slowly towards the earth. These ascending and descending vapors fill the entire space between the clouds and the earth, and become a conductor for the electricity of the clouds to pass off slowly and imperceptibly

to the earth, and the discharge of cloud-electricity by this cause is in proportion to the amount of the vapor held in suspension in the sub-cloud regions of the atmosphere. The humidity of the atmosphere in California, so contiguous to the Pacific Ocean, is naturally much greater than that found at points more remote from large bodies of water. At San Diego the mean humidity of the air in 1891 was 74 per cent of complete saturation; in 1892, 76 per cent; in 1893, 74 per cent, and the mean humidity for 11 years, from 1884 to 1894 inclusive, is 77 per cent. The discharge of electricity from the clouds through excessive humidity, known under the popular term of "free electrical conditions," may be given as one reason for the infrequency of thunderstorms in California. But this cannot be a sufficient reason, as the humidity of the atmosphere along the Atlantic coast in parallel latitudes, where thunderstorms are common, is probably as great as that on the Pacific coast.

The complete explanation of this anomaly will probably be found in connection with the course of cyclonic movements which pass over the continent from west to east, in immense gyrations of air saturated with moisture, which deposit their surplus moisture principally in the southeast quadrant, in the form of snow and rain. In all low barometer areas, the surrounding air naturally tends towards the warmer centre, and rises into the upper regions of the atmosphere, where the vapors carried upward are condensed, to descend as rain and snow. Along the vast stream of warm waters, forming the Japan current, coursing their way through the ocean from west to east, there is found an abundant source of food-supply for storms. Here originate the initiatory movements of cyclones which pass over the North American continent, and give California its rainy season. Storm centres move eastward at a lower latitude in winter than in the summer season, probably due to the apparent movement of the sun north and south of the equator. The sun's rays are less oblique in summer than in the winter season, and, therefore, have more heating power. Determined by this movement of cyclones, a dry season prevails during the summer over the region south of the forty-second parallel of latitude, and west of the one hundred and twelfth meridian. The cyclonic centres are deflected southward from October to April, passing into Oregon, and sometimes into northern California, although there is no record of a cyclonic

centre making an impact on the coast south of San Francisco. The absence of cyclones, which determine the precipitation of moisture, thus gives California its dry season from May to September, and naturally accounts for the absence of electrical storms during the summer.

It remains to be considered why cyclones, which pass over the State from September to May, precipitate their moisture in rain and snow, but the storms generated do not often exhibit electrical displays. This seems to be a puzzling problem, and several fanciful theories have been proposed to account for it. An amateur astronomer thinks the mountain peaks silently draw the electricity from the clouds, and thus rob them of their thunderbolts. He fails to inform us why this cause does not operate in other mountainous regions. Some maintain that the absence of thunderstorms is due to the clear skies of California. In other words there is a lack of cloud material to form thunderheads to produce electrical displays. This is evidently an effect resulting from meteorological conditions, and not a cause.

To account for this anomaly, we must consider the sources of atmospheric electricity. Free electricity in the atmosphere arises from three sources: (1) from evaporation and condensation; (2) from friction; (3) from heat. Probably the full solution of this question will be found in the connection between heat and the generation of free electricity in the atmosphere. Heat disturbs the molecules of a body, separates them, and thus modifies the electrical condition, so that currents of electricity are generated to restore the equilibrium. As water flows from a higher to a lower level, or as heat passes by conduction along a bar of iron unequally heated at its ends, so electricity generated by heat is transmitted from one body to another to equalize the condition of the two bodies. Every one has observed what is termed "heat lightning" at the end of a very hot day in summer. All are familiar with the experiment in the laboratory of the magnetic needle placing itself at right angles to a wire along which flows a current of electricity generated by the heat of a lamp. Heat in some unexplained manner produces a difference in potential, and thus generates electricity.

Heat is an important factor in electrical displays. Take, for example, a station in the middle latitudes where there are four seasons of the year. We notice that the storms of summer are

accompanied by electrical displays, but electrical disturbances are absent from winter storms. Heat makes this difference in the electrical conditions. As the seasonal temperature of the atmosphere is reduced, a point is reached in the late autumn, after which during the winter months, unless there comes an abnormally hot day, electrical disturbances cease. As the seasonal temperature increases in the spring a point is reached when the electrical disturbances become manifest again. It seems reasonable to conclude that the temperature of Southern California has passed below the point for the generation of free atmospheric electricity before the rainy season commences, and that it remains below that point until the low barometers cease to pass over this section of the State. The mean maximum temperature at San Diego from September to May, during the rainy season, is about 60°, and it is probable that during this period there is not enough heat to generate free electricity in the atmosphere.

Another fact conspires with the absence of heat to account for the infrequency of thunderstorms. Electrical currents are due to a difference of potential which depends on heat; yet simple elevation of temperature in a region does not generate free atmospheric electricity, but unequal distribution of temperature gives the electrical potential. Now, the temperature of Southern California, not counting the ranges of mountains, is not only low but quite uniform during the rainy season. The mean range of temperature for the months of October, November, December, January, February, and March for the year 1892 was 34.66°, for the year 1893, 37.50°. Under such a uniform temperature the electrical potential is very small, not enough to generate free electricity in the atmosphere. The electrical tiger in Southern California, we therefore conclude, is only asleep. A little more heat unequally distributed, and electrical fire would flash from the skies.

THE AUGUSTA, GA., TORNADO OF MARCH 20, 1895.*

W. J. WAMBAUGH.

THE tornado which passed over the south and southeast portions of this city at 9 A. M., of March 20, so far as known, was very local and wrought no damage except in the city and suburbs. Thirty or more small frame houses were demolished, and several larger and more substantially built structures were more or less damaged. No loss of life has been reported, though many of the demolished houses were occupied at the time. Considering the thickly populated nature of the territory traversed, the damage done was remarkably slight.

FACTS.

The conditions which preceded and accompanied the tornado were as follows:—

1. The 8 A. M. weather map showed a cyclone in the vicinity of Nashville, Tenn., the isobars of the same being very much elongated toward the southward and southeastward. When these lines were drawn to differences of .05 inch a secondary barometric depression of .10 in. was disclosed in the vicinity of Augusta.

2. Stratus clouds at an apparent elevation of less than two thousand five hundred feet were observed for several hours preceding the tornado as moving from southwest. After noon they gradually veered to west and northwest under the influence of the cyclone which was then passing over Tennessee and northern South Carolina.

3. During the passage of the tornado and for several hours following, heavy cumulus, and cumulo-stratus clouds, at an elevation of about one thousand feet, were moving from northwest.

4. The wind direction for twelve hours, ending at 5.40 A. M., had been steadily from the northeast. At that time it changed to east, remaining from east until 6.20 A. M., when it veered to southeast. At 7.20 A. M. it changed from southeast to south; at 9 A. M. from south to west; at 9.15 A. M. from west to northwest, remaining from northwest until 3 P. M.

* By permission of the Chief of the Weather Bureau.

5. The surface winds over a territory extending two hundred and twenty-five miles northward and northeastward and one hundred and fifty miles westward and northwestward were uniformly from the northeast, while those over the territory extending southward from Augusta, three hundred miles or more, were from south and southwest.

6. The southerly winds were very humid and warm while those from the northeast were more than twenty degrees colder.

7. The directions of the surface winds at this point were never in coincidence with those of the upper currents until after the formation of the tornado. The upper currents, as shown by the clouds, were not over two thousand five hundred feet above the ground, hence the local depression did not extend beyond that elevation.

8. The direction of the tornado was toward the east and east-northeast.

9. The funnel cloud was not unlike those usually accompanying tornadoes, and extended to the ground at but four points in its course of three and a half or four miles, remaining upon the ground each time for a distance of but three hundred to twelve hundred feet.

10. The direction of its revolution, as indicated by the distribution of debris, was from right to left. Heavy objects were lifted to a considerable height, the roof of one house being carried forward, evidently by the progressive motion of the storm, a distance of over five hundred feet. Its progressive velocity was estimated at about forty-two miles per hour. Quite a number of persons saw the cloud. Some described it as a large revolving ball driven forward by the wind. Its appearance, no doubt, varied according to the position of the observer. Several persons mentioned the presence of a peculiar light which is said to have illuminated portions of the funnel. Whether this light existed in fact or only in imagination I am unable to say. If present, it could hardly have been an electrical manifestation for, unlike most storms of a tornadic nature, lightning and thunder were entirely absent.

11. Secondary whirls seem to have occurred at two points, five hundred feet and fifteen hundred feet, respectively, southeast of the tornado's path.

12. The barograph at this office registered 29.74 in. at 1 A. M., and fell gradually until it registered 29.46 at 9 A. M., after which it rose suddenly to 29.56 by 10.30 A. M., and then fell to 29.41 by 3.10 P. M. After 3.10 P. M. it continued to rise uninterruptedly, and at 7 P. M. registered 29.48.

13. The local barometric depression amounted to .10 inch. If this depression had not been present the 29.80 instead of the 29.70 isobar would have passed over this place.

14. The local depression was in this vicinity for several hours preceding the tornado. During the night of the 19th its centre was southeast of this point. From 5.40 A. M. until 6.20 A. M., it was south; from 6.20 A. M. until 7.20 A. M., it was southwest; and from 7.20 A. M. until 9 A. M., it was west. These changes of position are indicated by the winds which veered from northeast at 5.40 A. M. to south by 7.20 A. M. The last position was either nearest to Augusta or the intensity of the depression had been much increased. Otherwise I could not account for the increased rate of fall in the barometer which occurred during these changes of position, or for the increase in velocity of the wind which had steadily grown from three miles at 5 A. M. to 24 miles at 9 A. M.

INFERENCES.

A study of the foregoing facts is quite interesting and leads me to the following conclusions:—

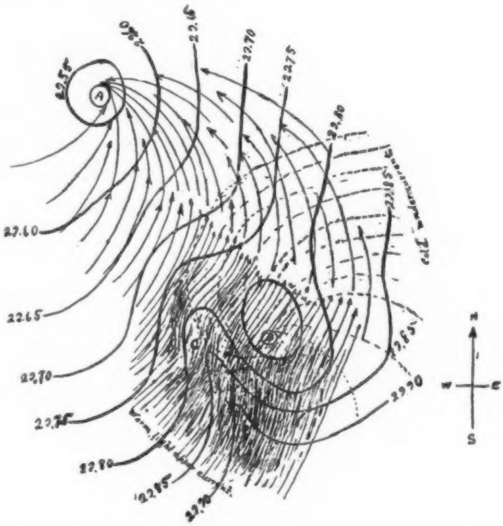
1. The tornado resulted at the moment when the local barometric depression came under the power of the main cyclone.

2. The local depression presented the conditions which were required in the formation of a tornado and without it the tornado would not have occurred.

3. The tornado was the instrument by which these conditions were removed, or in other words, by which the local depression was filled and restored to a level with the surrounding air. This filling was indicated by the rapid rise of the barometer immediately following the tornado,—the rise corresponding exactly to the degree of depression, viz., one tenth of an inch. After the depression was filled, the barometer was solely under the influence of the main cyclone, and fell gradually under such

influence until it registered its lowest figures at 3.10 P. M., — the time when the trough of the cyclone crossed this meridian.

The filling process continued from 9 A. M. until 10.30 A. M., but during that time the tornado was doubtless whirling onward in the upper currents toward the cyclone centre. It had interrupted the circulation of the lower currents, and gravity completed the task by causing the heavier surrounding air to flow into and fill up the depression.



4. In the figure we have represented the circulation of the currents about the main and secondary storm centres. A represents the main centre; B, the secondary centre. The solid lines represent the upper currents flowing into the main centre. The dotted lines show the under currents which were governed by the secondary centre.

The upper currents were not originally upper currents. Over Mississippi and western and southern Alabama they were lower currents, but as they moved toward the northeast they encountered the cold currents flowing toward the southwest. Being warm and light they rose by sliding over the cold and comparatively heavy currents. This sliding of one current upon the other increased the weight of the air over that territory, and, in

consequence, a ridge of high pressure is seen to extend from the southeast to C. This ridge of high pressure served as a wall of protection to the depression at Augusta, and enabled it to maintain its individuality for a longer period than would have otherwise been possible. With this wall of cold air on the west and a comparatively high pressure surrounding it from south to northeast, the southwest currents which were controlled by the main storm passed harmlessly over the local depression in the same manner as a breeze will pass over the hill-tops without materially disturbing the air in the valley below. But as the main cyclone approached, it exerted more and more influence upon the local depression, particularly upon the winds of its northwest quadrant, thus gradually breaking down the wall upon the west which had been built and sustained by the northeast winds of the northwest quadrant. With this wall weakened and the influence of the main storm greatly increased through proximity, the southwest current speedily came in contact with the revolving currents of the upper portion of the local secondary storm, and by imparting of its momentum, increased the rapidity of the revolutions of the latter. These currents at the time of their contact were revolving spirally upward from right to left about their respective storm centres, hence the whirl produced by their contact continued to extend upward and the under currents were drawn in below by the suction thus produced. During a short time the whirl extended to the earth's surface and resulted in the destruction already noted. The velocity of the whirl depended primarily upon the velocity of the upper southwest currents, and secondarily upon the depth of the local depression. When the depression began to be filled by the inflowing cold surface air, the whirl left the earth and gradually subsided in the upper air.

5. The ascending air column in the centre of the local depression made its escape by overflowing in the direction of the main storm centre. Upon the west, southwest, and south sides, it encountered the southwest currents of the main storm, and therefore could not overflow in those directions. Neither could the overflow be against the comparatively high barometric pressures on the southeast, east, and northeast. The only directions in which no opposition was encountered were north and northwest. The overflow was therefore a southwest wind

and an upper current which gradually became a part of the general circulation of the main storm.

6. The inflowing cold air lowered the temperature from 67° at 8.58 A. M. to 49° by 11.20 A. M. It seems reasonable to suppose that when the suction was produced by the whirl above, the warm light air at the surface would be the first to respond. This would account for the rapid fall in temperature and sudden inflow of cold air.

7. The cold surface air currents at Augusta came from west and northwest during and after the passage of the tornado. They were doubtless flowing from the wall of high pressure which had been formed to the westward. They continued to flow for one and one half hours, or apparently until that wall had entirely flowed away and found its level by filling our local depression.

8. All cyclones which are accompanied by tornadoes have their isobars elongated toward the tornado region. Were data always available to permit of drawing the lines to differences of .05 inch, it is very probable that local depressions of small areas and intensities would be noted as the predisponent of all tornadoes.

WEATHER BUREAU, Augusta, Ga., April 8, 1895.

PSYCHIC EFFECTS OF THE WEATHER.*

EDWARD A. BEALS.

THE impressed forces, apart from hunger, which have done more than anything else to change the state of mankind, are those pertaining to the weather. No matter how much we may grumble and find fault with its ever-varying changes, we ought always to remember that this property of variability is a powerful agent, undoubtedly introduced for the express purpose of causing men to move about. It is not hard for me to conceive how the influence of cold might have impelled primitive man to rush out of his cave, and, with club in hand, slay some weaker or less cunning animal, that he might thereby use its skin as a protection from climatic rigor. Our natures, both

* Read at Minneapolis, Minn., before the Minneapolis and St. Paul Academies of Science, March 6, 1895.

morally and physically, have been vastly influenced through the introduction of clothing, and if we accept this hypothesis, it was originally due more to weather extremes than to modesty. It is doubtful if mental evolution without changeable weather conditions could have made any progress worth speaking of, and instead of the civilization that now surrounds us we would yet be in that state described by Mr. Darwin as a "tailed quadruped, probably arboreal in its habits."

Before the advent of Christianity many offerings and sacrifices were made to appease deities believed to control the winds, the thunder, and other atmospheric phenomena, and it may be that one cause of the universality of polytheism was owing to the inability of the existing mind to conceive how such diversified weather could be made by a single Deity. A cloud obscuring the sun at the time of the summer solstice was esteemed a very bad omen by the semi-civilized Incas, and a whole nation could thus be thrown into despondency and gloom by the occurrence of this, to us, easily explained natural phenomenon.

Plutarch says that when Hannibal first came into Italy with his victorious army, the alarm and consternation of the Romans were greatly augmented by the prodigies then happening, which, besides the more common signs of thunder and lightning, consisted of a rainfall of red-hot stones, and the letting down of several scrolls from the heavens, upon one of which was plainly written, "Mars himself stirs his arms." The rainfall of red-hot stones was probably of volcanic origin, and the scrolls an aurora, with the writing an illusion, due to a fevered imagination. It can thus easily be seen how the terror inspired by unusual meteorological conditions must in olden times have often determined the course of great historical events.

For the purpose of pacifying the anger of deities held responsible for phenomenal weather, ceremonies, and even sacrifices, are still made by the uncivilized tribes of to-day. One of the popes thought bad weather the sole product of the "evil one," and had a manual prepared to be used by the clergy on suitable occasions, for the purpose of expelling those demons held responsible for its disagreeable features, and the Catholic "Key to Heaven" and the Episcopal Prayer Book yet contain prayers for fair weather and for rain.

Salutations in nearly all ages and countries are more or less

marked by climatic environment as well as religious sentiment, while they also tend to show how much all the world is interested in the weather. Among Orientals the Persian greeting of "May your shadow never be less"; the Arabian of "May God strengthen your morning"; and the Egyptian of "How goes the perspiration?" all typify a feverish, burning climate, with violent light and strong shadows, whereas in the occident the abrupt "Good morning," "*Wie gieht es*," or "*Bonjour*," indicate a muggy, windy, or chilly climate, and are characteristic of industry, hurry, and restlessness. The ceremonies of salutation in the East are extremely passive, and frequently occupy five, ten, or even more minutes before they have been punctiliously complied with.

Ancient weather prophets largely based their prognostications upon the restlessness of animals, and numerous are the proverbs handed down to us in commemoration of this fact. As an illustration, an unknown writer says: —

> "But with the changeful temper of the skies,
> As rains condense and sunshine rarefies,
> So turn the species in their altered minds
> Composed by calms and discomposed by winds."

And a concordant distich by Shakespeare is: —

> "If the sun sets weeping in the lowly west
> Witnessing storms to come, woe and unrest."

Major Dunwoody's collection of weather proverbs includes a long list of animals thus affected; and the psychical information bearing on this subject, which is embraced within the covers of this little book, is unsurpassed by any other publication.

Seneca said: "The empire of the world has always remained in the hands of those natures who enjoy a mild climate." This may have been true in his time, but it is now no longer so, for that climate which maintains the highest civilization and stimulates the mind to its greatest activity, is one where there is a moderately severe winter, calling forth careful forethought during the preceding summer in order that the discomforts attached to the rigorous season may as far as possible be artificially lessened. It is true, however, that the inhabitants of all the world are indelibly impressed with the effects of permanent climate.

"The cold in clime are cold in blood,
Afric is all the sun's, and as her earth
Her human clay is kindled."

Then again Seneca affirms that "those who dwell near the frozen north have uncivilized tempers." It is quite probable the uncivilized tempers Seneca attributes to the frozen north were due more to the existing state of civilization during his time, than to the permanent effects of climate, as it is now conceded that those of the north are phlegmatic in disposition and not so excitable as are their more sensitive and irritable contemporaries of the south.

As the weather affects the minds of those subjected to its permanent influences, so likewise are all natures more or less swayed by its seasonal and even by its diurnal variations. Those having delicate and refined temperaments, like poets and prose poetic writers, are more susceptible to these changes than ordinary people, although all readily respond when in poor health.

Those with lingering diseases die more often at the change of weather; and the mortality reports of Dr. Farr, of England, and Dr. Stark, of Edinburgh, show the mild and temperate months to be the healthiest, while those either of extreme heat or extreme cold or of excessive moisture, invariably swell the death rate.

It is said that a sudden rise of temperature predisposes those liable to an attack of mania, and that one sign of growing neurotic diathesis is an inability to keep at the top of one's condition and in good tone in unusual weather. In Texas, Dr. Cline states that the number of deaths caused by diseases of the nervous system is fifty per cent greater on days with abnormally high temperature than on days with normal temperature, and that equable conditions in pressure and temperature are favorable for the treatment of these diseases.

A German doctor who accompanied Napoleon's army during its retreat from Moscow has furnished us with an interesting account regarding the action of intense cold on the minds of the soldiers who participated in this memorable event. His observations show quite conclusively that very low temperatures cause a diminution in will power and often a temporary weakening of the memory, which, in some instances, he affirms, resulted in a permanent derangement of the mental faculties. Dr. Rose, in a paper published in a New York medical journal, quotes him as saying that:

"With the first appearance of moderately low temperature, about 5° above zero, many of the soldiers were found to have forgotten the names of the most ordinary things about them, as well as those of the articles of food, for the want of which they were perishing. Many forgot their own names and those of their comrades, which was noted in the strong as well as in the weak. Others showed more pronounced symptoms of mental disturbance, and not a few became incurably insane." These men were dispirited, poorly clad, and many were weakened by disease and hunger, therefore the cold was not alone responsible for these effects, as zero weather is rather stimulating than otherwise in its action upon the well fed and healthy. Its inducing agency, however, cannot be altogether neglected, and there is probably no person ever having been exposed to very cold weather who has not noted some degree of mental lethargy when in an uncomfortably chilled condition.

Religious fervor is considerably diminished by low temperatures, if we accept the conclusions arrived at by a Baptist preacher, who flourished hereabouts for a number of years during the early Minnesota days. It is related that at a prayer meeting, one bitter cold night, he requested the rather small congregation to draw up near the stove, as his observations had led him to believe that cold weather was not conducive to piety.

As opposed to cold air which, when not too severe, is bracing and highly stimulating, we find that hot air is always depressing and relaxing. It causes languor and lassitude, and when abnormally warm, entails oppressed breathing.

The operation of hot and cold on the human sensibilities was remarked upon by Sidney Smith, whose rather sophistical deductions were that: "Very high and very low temperatures establish all human sympathy and relations. It is impossible to feel affection above 70° or below 20° Fahr. Human nature is too solid or too liquid beyond these limits. Man lives to shiver and perspire." Ben Jonson, on the other hand, ridiculed such ideas and claimed that the mind was imponderable, immortal, and beyond the reach of earthly influences.

No matter which view we accept, there are but few if any of us, even when in good health, who have not experienced times when everything appears dark and gloomy, when little ills are magnified into terrible evils, and we have what is called a fit of

the "blues." These depressed mental states are most frequent on dull, disagreeable days, when the air is muggy and the pressure least, or when thunderstorms are imminent and the electrical potential or the wind has changed. It is also on such days that domestic animals become so restless; when hens sit on the fence and oil their feathers, or the cat is morose and peevish. Teachers and jailers often note that a spirit of restlessness asserts itself among their charges during such weather, and on these days commercial travellers aver that "there is no use in trying to do business to-day." Suicides are then most frequent and every one is inclined to be cross and irritable.

Attention has been called to the controlling effect of this weather on work by Dr. Crothers, of Hartford, Conn., who says: "In my own case I have been amazed at the faulty deductions and misconceptions which were made in damp, foggy weather or on days in which the air was charged with electricity, and thunderstorms were impending. What seemed clear to me at these times appeared later to be filled with error. An actuary in a large insurance company is obliged to stop work at such times, finding that he makes so many mistakes which he is only conscious of later, that his work is useless. In a large factory, from ten to twenty per cent less work is brought out on damp days and days of threatening storm. The superintendent in receiving orders to be delivered at a certain time, takes this factor into calculation."

The clergy who study their congregations are aware that they are as impressible by weather conditions as is mercury. A very hot day, in which there is no wind and where there is not a breath of morning air, is one in which no eloquence will interest an ordinary audience. While a morning in which the sun shines brightly, and there is a gentle, warm, not hot, wind, will call out all the powers of the soul and every faculty of the mind is alert and open to the slightest impression. Such a day fills our avenues with gay people, and the hearts of the covetous shopkeepers are made glad by increased sales and overflowing coffers, while even the busy clerks are unusually pleasant and agreeable. The opposite conditions of wet, windy, or sloppy weather seem also to correspondingly influence the spirits of some people, for on these days they are likewise possessed with a strong inclination to go out into the streets or fields, and

some of them have told me that they have to exert considerable will power to prevent themselves from doing so.

From Foster's Encyclopædia of Natural Phenomena is culled the information that dreams of a hurrying and frightful nature and imperfect sleep are frequent indications that the weather is changed or about to change, and that these nocturnal symptoms are experienced by many persons on a change of wind, particularly when it becomes east. When from this quarter it makes most people uncomfortable and produces headaches in persons who are subject to them.

In some portions of South America the north wind, when coming from the equatorial regions, seems to affect the dispositions of the inhabitants; and one writer affirms that at La Plata it amounts to little less than a temporary derangement of the moral faculties, as then cases of quarrelling and bloodshed are much more frequent than at any other time.

There is a very interesting article upon the subject under discussion in the January, 1894, number of the "American Journal of Psychology," by Prof. J. S. Lemon, upon which I have drawn freely for material here used. He concludes by stating that, "All our senses put us in rapport with the external world. The knee-jerk seems proven to have a weather factor. It is not strange if the eye, *e. g.*, which wants the normal stimulus, in long dark weather causes other changes. Changing moisture in the air changes odors, and many appetites are affected, as touch is still more obviously. Tea tasters work best on fair days."

There have been a number of instances where our leading writers have found it impossible to make any headway unless the weather conditions were favorable. Its depressing as well as exhilarating effects can be traced to a most surprising extent in the works of poets and prose poetic writers.

Dante says, —

> "Now is the hour that wakens fond desire in men at sea,"

and Gray, —

> "The curfew tolls the knell of parting day,"

and then puts down, in exquisite forms, thoughts suitable to the hour and place in which he stood.

If we look at Burns we see the same principle at work. The Lazy Mist says, —

> "The forests are leafless, the meadows are brown,
> And all the gay foppery of summer has flown";

then following he says, —

> "Apart let me wander, apart let me muse;
> How quick time is flying, how keen fate pursues."

In Burns' "Farewell to his Country," we see the same thing exactly: —

> "Across her placid, azure sky
> She sees the scowling tempest fly,
> Chill runs my blood to hear it rave,"

and so on.

John Ruskin is correspondingly affected in that beautiful pen picture of an English misty dawn where he says: "Morning breaks, as I write, along those Conneston Fells; the level mists, motionless and grey, veil the lower woodlands and the sleeping village, and the long lawns by the lake shore. Oh, that some one had told me in my youth how little a love of colors and clouds would serve me when I should look for those whom I shall never see more."

To follow the effect of weather upon the literature would be nearly an endless task, but to do so would remove any doubts one might still have regarding its quickening or slackening of the highest affections of the soul.

It has always been a great mystery to me when, in view of the knowledge we now have regarding the effects of weather upon all life, whether animal or vegetable, and as I have now shown, influencing the highest mental faculties, that so important a factor does not receive greater attention from our physicists and social reformers, and especially at our universities.

CURRENT NOTES.

Royal Meteorological Society.—At the meeting of this Society on Wednesday evening, March 20 ,Mr. W. N. Shaw, F. R. S., delivered a lecture on "The Motion of Clouds considered with reference to their mode of formation," which was illustrated by experiments.

The question proposed for consideration was how far the apparent motion of cloud was a satisfactory indication of the motion of the air in which the cloud is formed. The mountain cloud cap was cited as an instance of a stationary cloud formed in air moving sometimes with great rapidity; ground fog, thunder-clouds, and cumulus clouds were also referred to in this connection.

The two cases of formation of cloud were next considered, viz., (1) the mixing of masses of air at different temperatures, and (2) the dynamical cooling of air by the reduction of its pressure without supplying heat from the outside. The two methods of formation were illustıated by experiments.

A sketch of the supposed motion of air near the centre of a cyclone showed the probability of the clouds formed by the mixing of air being carried along with the air after they were formed, while when cloud is being formed by expansion circumstances connected with the formation of drops of water on the nuclei to be found in the air, and the maintenance of the particles in a state of suspension, make it probable that the apparent motion of such a cloud is a bad indication of the motion of the air.

After describing some special cases, Mr. Shaw referred to the meteorological effects of the thermal disturbance which must be introduced by the condensation of water vapor, and he attributed the violent atmospheric disturbances accompanying tropical rains to this cause.

The difference in the character of nuclei for the deposit of water drops was also pointed out and illustrated by the exhibition of colored halos formed under special conditions when the drops were sufficiently uniform in size.

Annual Report of the Meteorological Council to the Royal Society. — The annual report of the Meteorological Council to the Royal Society for the year ending March 31, 1894, is issued. The Council remains the same as during the year 1893, and consists of the following gentlemen Lieut.-Gen. Richard Strachey, R. E., C. S. I., LL.D., F. R. S., chairman ; Mr. Alexander Buchan, M. A., LL.D., F. R. S. E.; Prof. George Howard Darwin, M. A., LL.D., F. R. S.; Mr. Francis Galton, M. A., D. C. L., F. R. S.; Mr. Edward J. Stone, M. A., F. R. S., and Capt. William J. L. Wharton, R. N., F. R. S., Hydrographer of the Admiralty.

The report is, as usual, divided into four parts, Ocean Meteorology, Weather Telegraphy, Land Meteorology, and Miscellaneous. During the year 1893–94, the verifications of 8.30 P. M. forecasts were as follows: complete success, 59; partial success, 25; partial failure, 11; total failure, 5; which gives a total percentage of success, 84. During the nine years, 1884–1893, this percentage of verification has been attained three times, in 1885, 1887, and in 1893. The 1893 percentage of complete success is the highest on record.

Mr. R. H. Curtis contributes a note on the "Performance of the Pressure-Tube Anemometer on the roof of the Meteorological Office."

Director of the Canadian Weather Service. — Mr. R. F. Stupart, formerly assistant to Mr. Charles Carpmael, lately deceased, has succeeded the latter as Director of the Canadian Meteorological Service.

BIBLIOGRAPHICAL NOTES.

RAINFALL AND SNOW OF THE UNITED STATES.

MARK W. HARRINGTON. *Rainfall and Snow of the United States as Compiled to the End of* 1891, *with Annual, Seasonal, Monthly, and other Charts.* United States Department of Agriculture, Weather Bureau, Bulletin C. Washington, D. C., 1894. Atlas, 18 x 24 inches, charts 23. Text, 4to, 80 pp.

This latest publication of the Weather Bureau is one which will prove very useful to everyone who is studying the climate of the United States. The statistics of rain and snow here given include the most important series of observations that have been made from the early settlement of the country to the close of the year 1891, so that the charts are up to date as nearly as they can be at present. The records were taken from the following sources: the Smithsonian Institution, the published journals of scientific societies and other associations, the Medical Department of the United States Army, the Lake Survey, the Regents of the University of the State of New York, the Central and Southern Pacific Railways, the various State Weather Services, and Meteorological Associations, the Signal Service, and, finally, the Weather Bureau. Great care has been taken to have the results as accurate as possible by a comparison of the records at different stations with those of surrounding stations situated under approximately similar conditions, and by checking the observations by comparison with those obtained by the trained observers of the Signal Service and Weather Bureau. The actual work of preparing the tables was intrusted to a force of clerks under the supervision of First Lieut. B. M. Purssell, 19th United States Infantry, detailed for temporary duty with the Weather Bureau, and, after Lieut. Purssell's relief from duty, Mr. George F. Flint, and later Mr. A. J. Henry, had charge of the tabulation. A board composed of Major H. H. C. Dunwoody, Lieut. Purssell, and Prof. H. A. Hazen had charge of the construction of the isohyetal charts, prepared under the direction of Lieut. Purssell.

The Atlas contains twenty-three charts, 18 by 24 inches in size. These charts are as follows: monthly rainfall; seasonal rainfall; annual rainfall; monthly snowfall; monthly maxima of rainfall; rainy seasons; monthly minima of rainfall; details of rainfall; details of occurrence of thunderstorms. The charts are all extremely useful and are well adapted to serve as illustrations for use in the class-room. There are eight small charts showing the monthly maxima and minima of rainfall by seasons, the regions of maximum and minimum rainfall being clearly indicated by colored lines, the coloring varying with the different months. Ten small charts give inter

esting information regarding details of rainfall, such as the migration of the region of least rainfall; seasons of greatest rainfall by States; isohyetal of over 40 inches annual rainfall; annual probability of rain; greatest probability of rain; least probability of rain; heaviest daily rainfall recorded; greatest number of consecutive days with rain or snow; greatest number of consecutive days without rain or snow.

The text accompanying the atlas is a valuable compendium of information regarding our rainfall and snowfall. Space will not permit any extended notice of this report, which should most certainly be carefully studied by all who wish to be informed on this subject. The publication as a whole is one of the best the Weather Bureau has issued.

SURFACE CURRENTS OF THE GREAT LAKES.

Mark W. Harrington. *Surface Currents of the Great Lakes, as deduced from the Movement of Bottle Papers during the Seasons of* 1892, 1893, *and* 1894. U. S. Department of Agriculture, Weather Bureau, Bulletin B., Revised edition, Washington, D. C., 1895. xiv pp., VI charts. 18 x 24 inches.

This is a revised edition of Weather Bureau Bulletin B, which was noticed in this Journal for May, 1884, pp. 34, 35. In the Letter of Transmittal, Prof. Harrington says that "this publication is intended to meet the demands of commerce by showing where flotsam and jetsam may be looked for; what allowance should be made in fog when speed is checked down; and to enable masters of vessels to so lay their courses as to take advantage of the drift." The charts in this revised edition are based on results derived from a study of the movements of bottle papers during three seasons, 1892, 1893, and 1894, whereas in the first edition only two seasons' records were used. As a result of this more detailed study the currents of the Great Lakes are found to vary in velocity, in a general way, between 3 and 20 miles a day. In some cases velocities of 30 to 40 miles a day have been found; but these velocities are thought to be due to surf motion rather than to the motion of the surface water as a whole.

The present edition of the Bulletin gives a detailed record of bottle papers floated and recovered on Lake Superior during the seasons of 1892, 1893, and 1894. The charts show the bottle paper courses for each lake during the three years, the special drifts, and the resultant currents.

TITLES OF RECENT PUBLICATIONS.

FURNISHED BY MR. OLIVER L. FASSIG, LIBRARIAN, U. S. WEATHER BUREAU, WASHINGTON, D. C.

(An asterisk [*] indicates that the publications thus designated have been received by the Editor of this JOURNAL.)

ANGOT, ALFRED. *Les aurores polaires.* (Bibliothèque scientifique internationale.) 8vo. Paris, 1895. vii, 318 pp. 11 pl.

ANNALEN DER SCHWEIZERISCHEN METEOROLOGISCHEN CENTRAL-ANSTALT. 29 Jahrgang 1892. 4to. Zurich, (1894) x, 250, 156 pp. 13 pl.

FORTSCHRITTE DER PHYSIK IM JAHRE 1893. Dargestellt von der Physikalischen Gesellschaft zu Berlin. 49 Jahrgang. *Erste Abth. Physik der Materie.* Redigirt von Richard Bœrnstein. 8vo. Braunschweig, 1895. lxx, 562 pp. (The Berlin Physical Society is now endeavoring to issue the *Fortschritte* more nearly up to date. In addition to the above part, the volumes for 1888 have just been completed. Hereafter the current volume and one of the back volumes will be issued each year until the gap is filled.)

FORTSCHRITTE DER PHYSIK IM JAHRE 1889. 45 Jahrgang, 1889. *Erste Abth.*, enthaltend: *Physik der Materie.* 8vo. Braunschweig, 1895. lxviii, 580 pp.

HUNGARY. K. UNG. CENTRAL-ANSTALT FÜR METEOROLOGIE UND ERDMAGNETISMUS. *Jahrbuecher.* XXI Band. Jahrgang 1891. 4to. Budapest, 1894. xix, 177 pp.

* INDIAN METEOROLOGICAL MEMOIRS. Published under the direction of J. Eliot, Meteorological Reporter to the Government of India. Vol. V. I. *The diurnal variation of atmospheric conditions in India; being a discussion of the hourly observations recorded at twenty-five stations since* 1873 Part VI. *Containing the discussion of hourly observations made at Agra.* Fol. Calcutta, 1894. Pp. 273-315.

ITALY. ANNALI DELL' UFFICIO CENTRALE METEOROLOGICO E GEODINAMICO ITALIANO. Serie seconda. Vol. XII. Parte II. 1890. Fol. Roma, 1895. 383 pp. Contents: *Record of observations in Italy during the year* 1890.

* LANCASTER, A. *Le climat de la Belgique en* 1894. In: Annuaire de l'Observatoire Royal de Belgique. 1895 (62d year). Pp. 306–485, 3 pl. 16°. Bruxelles, 1895.

LIVONIA. *Bericht ueber die Ergebnisse der Beobachtungen an den Regenstationen der kaiserlichen livlændischen gemeinnuetzigen und okonomischen Sozietæt für das Jahr* 1893. 4to. (Dorpat, 1894.) 15 pp.

MANILA. OBSERVATORIO METEOROLÓGICO. *La meteorologia en la Exposición Colombina de Chicago* (1893). Memoria escrita por los P. P. Federico Faura y Jose Algue, Comisionados del Gobierno Español. Fol. Barcelona, 1894. 118 pp.; many figures in text.

MARCHI, LUIGI DE. *Sulla teoria dei cicloni.* Pubblicazioni del Reale Osservatorio di Brera in Milano. No. XXXVIII. Fol. Milano, 1893. 42 pp. 15 pl.

MARCHI, LUIGI DE. *Sulla teoria dei cicloni.* Nota II. (Extr. from: Rendiconti del R. Instit. Lombardo, Ser. II. Vol. XXVI. Fasc. XVI.) 8vo. (Milano, 1893.) 14 pp.

MARCHI, LUIGI DE. *Il più grande ghiacciaio del mondo.* (Extr. from: Boll. del Club Alpino Italiano. Vol. XXVI., 1892, No. 59.) 8vo. Torino, 1893. 24 pp.

MILL, HUGH ROBERT. *The realm of nature. An outline of physiography.* University Extension Manuals. 12mo. New York, 1894. (Chapter VII., *The*

atmosphere; Chap. VIII., *Atmospheric Phenomena;* Chap. IX., *Climates of the World;* Chap. X., *The Hydrosphere.*)

PUEBLA. *Observaciones meteorologicas del Colegio Catolico del Sdo. Corazón de Jesús.* Año de 1894. Fol. Puebla, 1894. 14 pp. 1 table.

REPORT OF THE SIXTY-FOURTH MEETING OF THE BRITISH ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE, held at Oxford in August, 1894. 8vo. London, 1894. cviii., 852, 118 pp., 4 pl. 1 table.

PRINCIPAL METEOROLOGICAL CONTENTS.

BUCHAN, A. *Meteorological observations made on Ben Nevis.* Report of the Committee of the British Association, pp. 108–116.

CLAYDEN, A. W. *The application of photography to the elucidation of meteorological phenomena.* Fourth report of the Committee of the British Association, pp. 143, 144.

DE RANCE, C. E. *The circulation of underground waters.* Twentieth report of the Committee of the British Association, pp. 283–302.

RAVENSTEIN, E. G. *The climatological and hydrographical conditions of tropical Africa.* Third report of a Committee of the British Association, pp. 348–354.

LANGLEY, S. P. *On recent researches in the infra-red spectrum*, pp. 465–474, 3 pls.

RÜCKER, A. W. Address of the President of Section A. (Mathematical and Physical Section.) *Terrestrial magnetic surveys*, pp. 543–554.

LORD KELVIN, MAGNUS MACLEAN, ALEXANDER GALT. *Preliminary experiments to find if subtraction of water from air electrifies it*, pp. 554, 555.

SCHUSTER, ARTHUR. *A suggested explanation of the secular variation of terrestrial magnetism*, pp. 571, 572.

CULVERWELL, EDWARD P. *On the inadequacy of the astronomical theory of ice ages and genial ages*, pp. 660, 661.

WHARTON, J. L. Address of the President of Section E. Geography. *The sea*, pp. 699–710.

DICKSON, H. N. *On the currents of the Faeros, Shetland Channel, and the North Sea*, pp. 713, 714. (Full report in the Report of the Fishery Board for Scotland, 1894.)

* RUSSELL, THOMAS. *Meteorology. Weather, and methods of forecasting. Description of meteorological instruments and river flood predictions in the United States.* 8vo. New York and London, 1895. xxiii, 277 pp., 46 pls.

SCHOTT, CHARLES A. *Magnetic survey of North America.* (Extract from Part II. of the Report of the Chicago Meteorological Congress, August, 1893, pp. 460–464.) 8vo. (Wash., 1895.)

TILLO, GEN. ALEXIS DE. *Magnetic survey of Europe and Asia.* (Extract from Part II. of the Report of the Chicago Meteorological Congress, August, 1893. Pp. 465–469). 8vo. (Wash., 1895.)

* U. S. WEATHER BUREAU. *Wreck and casualty chart of the Great Lakes*, 1894. One chart, with text, 25 x 36 inches. February, 1895.

WEATHER AND CROPS. Official publication of the Illinois State Weather Service. Chas. E. Linney, Ass't Director and Editor. Vol. I. No. 1. January, 1895. 4to. Chicago, 1895. 9 pp.